Reactive Transport Modeling of the Yucca Mountain Site, Nevada

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The Yucca Mountain site has a dry climate and deep water table, with the repository located in the middle of an unsaturated zone approximately 600 m thick. Radionuclide transport processes from the repository to the water table are sensitive to the unsaturated zone flow field, as well as to sorption, matrix diffusion, radioactive decay, and colloid transport mechanisms. The unsaturated zone flow and transport models are calibrated against both physical and chemical data, including pneumatic pressure, liquid saturation, water potential, temperature, chloride, and calcite. The transport model predictions are further compared with testing specific to unsaturated zone transport: at Alcove 1 in the Exploratory Studies Facility (ESF), at Alcove 8 and Niche 3 of the ESF, and at the Busted Butte site. The models are applied to predict the breakthroughs at the water table for nonsorbing and sorbing radionuclides, with faults shown as the important paths for radionuclide transport. Daughter products of some important radionuclides, such as ^{239}Pu and ^{241}Am, have faster transport than the parents and must be considered in the unsaturated zone transport model. Colloid transport is significantly affected by colloid size, but only negligibly affected by kinetic declogging (reverse filtering) mechanisms. Unsaturated zone model uncertainties are discussed, including the sensitivity of breakthrough to the active fracture model parameter, as an example of uncertainties related to detailed flow characteristics and fracture-matrix interaction. It is expected that additional benefits from the unsaturated zone barrier for transport can be achieved by full implementation of the shadow zone concept immediately below the radionuclide release points in the waste emplacement drifts.